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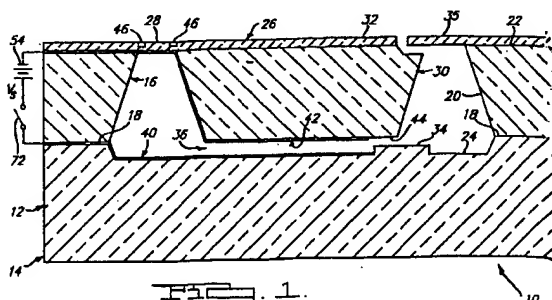
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(54) **A method for establishing a value for the sensitivity of an acceleration sensor.**

(57) A method of establishing a value for the sensitivity of an acceleration sensor, the sensor having a rigid frame (12), an inertial sensing mass (30) supported by the frame (12) and displaceable from a first position relative to the frame (12) towards a second position of maximal displacement relative to the frame (12) in response to acceleration inputs applied to the frame (12) along a sensing axis, and means (46) responsive to sensing mass displacement for generating an output signal, the method comprising the steps of: receiving a first value for the output signal when subjecting the sensing mass

(30) to a reference field, wherein subjecting the sensing mass (30) to the reference field simulates application of a first acceleration input to the frame (12), the reference field displacing the sensing mass (30) to a third position intermediate the first and second positions; receiving a second value for the output signal in the absence of subjecting the sensing mass (30) to the reference field; and determining the sensitivity value using the first and second values for the output signal and the magnitude of the simulated first acceleration input.





European Patent
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EUROPEAN SEARCH REPORT

Application Number

EP 93 10 0645

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	PATENT ABSTRACTS OF JAPAN vol. 012, no. 319 (P-751)(104) 30 August 1988 & JP-A-63 085 461 (AISIN SEIKI) 15 April 1988	1	G01P21/00 G01P15/12
Y	* abstract *	2	
Y	MEASUREMENT TECHNIQUES vol. 25, no. 6, June 1982, NEW YORK US pages 516 - 518 ARTYUKHOV ET AL 'Ways of improving second-class standard rotating platforms' * page 516 *	2	
P,X	DE-C-3 717 677 (BMW) * the whole document *	1,2,6	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			G01P
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 16 MARCH 1993	Examiner JONSSON P.O.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	



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(54) **Detector having self-calibration function**

Messaufnehmer mit Selbsteichfunktion

Détecteur avec fonction autocalibrage

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EP 0 606 115 B1

Description**BACKGROUND OF THE INVENTION**5 **Field of the Invention**

The present invention relates to an electrostatic capacity type acceleration sensor having a self-calibration function.

10 **Related Art Statement**

Hitherto, a conventional detector has been, as disclosed in, for example, JP-A- 61-31952, arranged in such a manner that the measuring operation is stopped so as to start a calibrating operation which is performed as the offline work. Furthermore, there has been disclosed, in JP-A- 61-212753, an apparatus capable of diagnosing deterioration by analyzing the characteristics observed in the detector. However, the apparatus of this type also performs, as the offline work, the operation for diagnosing the deterioration.

The conventional calibration has been realized for the purpose of automating the offline work. Furthermore, there has been a proposal that the reliability of a detector is improved by observing the line and giving an alarm if necessary as the online work. However, since no measure has been taken for performing the calibration as the online work, a problem takes place that the measurement is stopped for a relatively long time in comparison with the time in which the value of the measurement can be changed.

From GB-A-2 178 856 an electrostatic capacity type acceleration sensor including the features of the first part of claim 1 is known. This prior art sensor employs the closed loop technique in which the inertia mass electrode is maintained in a neutral position by applying a voltage. The quantity of this voltage corresponds to the acceleration being effective on the sensor.

25 From DE-A-35 42 397 a piezoelectric acceleration sensor is known in which an actuator in form of the piezoelectric plate is provided to diagnose the sensor portion. By applying a test voltage to the piezoelectric plate the sensor portion is deformed so as to measure a voltage to diagnose this portion.

Further, from EP-A-0 368 446 citable as a prior art according to Art. 54(3) EPC a self-calibrating acceleration sensor of the beam resistor type is known in which the detection signal of a beam resistor is used to measure the acceleration and to diagnose the sensor.

Summary of the Invention

35 It is the object underlying the invention to provide an electrostatic capacity type acceleration sensor enabling a simple and reliable on-line diagnosis and a method thereof.

This object is met by a sensor according to claim 1 and a method according to claim 3. Preferred embodiments are disclosed in the depending claims.

In a sensor, the calibration or the corrective operation must be completed in a significantly short time in comparison with the time in which the value of the measurement can be changed. The reason for this lies in that the data of the measurement must be protected from a disorder or an error due to the calibration or the corrective operation performed during the measurement operation. As for the device for processing an electric signal, significantly high speed semiconductor ICs are available recently due to the progress of the LSI technology. Therefore, the thus realized speed of processing the electric signal can cope with the time of several tens to 100 μ s which is the value necessary to conduct measurements in automobile in which the values to be measured are varied in a relatively short time.

45 Accordingly, the present invention employs stimulating means disposed adjacent to the detection means so as to stimulate and operate the detection means. A structure can be realized in which a small sensor, the size of which is, for example, several hundreds of μ m, and an actuator, that is, the stimulating device can be integrally formed by utilizing the micromachining technology for silicon or the like which has been remarkably progressed recently. Therefore, a compact and integrally formed stimulating device is able to apply a calibration signal, as a stimulation, to the detector without delay.

50 The sensor according to the present invention is preferably structured such that the stimulating means is formed adjacent to and integrally with the detection means so that the calibration signal can be supplied through the stimulating means. Therefore, the delay of response from the sensor can be significantly prevented. Furthermore, a high-speed signal processing circuit can be employed to shorten the time required for completing the self-calibration in comparison to the time in which the values to be measured are changed. Therefore, even if the self-calibration is performed during the measurement operation, the output from the sensor can be protected from disorder. Therefore, a so-called "online calibration" can be realized.

Furthermore, the characteristics obtained during operation are always corrected in accordance with a comparison

made with the initial characteristics of the sensor based on a calibration and corrective algorithm previously prepared in the processing means. Therefore, the initial performance can be maintained to significantly improve the reliability.

Other and further objects, features and advantages of the invention will be made more apparent by the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates the basic structure of an embodiment of the present invention;

Fig. 2 is a circuit diagram for a signal processing means; and

Figs. 3 and 4 illustrate the operations of semiconductor acceleration sensors.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to Fig. 1, the basic structure of an embodiment of the present invention will be described. Reference numeral 1 represents detection means and 2 represents stimulating means disposed adjacent to the detection means 2 and integrally therewith. Reference numeral 3 represents an assembly of the detection means 1 and the stimulating means 2. Reference numeral 4 represents a signal processing means structured as shown in Fig. 2 and arranged to supply a power supply voltage E_x for operating the detection means 1 and the stimulating means 2 and to process a calibrating signal to be supplied to the stimulating means 2. Furthermore, the signal processing means 4 has a so-called "signal adjustment function" capable of amplifying/converting a responding output signal from the detection means 1. In addition, the signal processing means 4 has a function of calibrating the input/output and a characteristic corrective function realized by digital-data processing performed by a microcomputer 44. Reference numeral 5 represents a detector including the above-described elements. Usually, the detector converts an acceleration into a digital quantity of a certain number of bits so as to output it. Reference numeral 7 represents a communication device capable of transmitting/receiving a command signal and an output signal to and from the signal processing means 4, the communication device 7 further having a function of displaying the command signal and the output signal.

Fig. 2 illustrates the specific structure of a circuit serving as the signal processing means 4. In response to a command issued from the microprocessor 44 having a memory 45 and a clock 46, a multiplexer 411 is operated so as to cause the output signal transmitted from the detection means 1 to be received by an amplifier 412a and an analog-to-digital converter 42. As a result, the output signal thus received is converted into a digital signal. In accordance with the value represented by the digital signal, the signal processing means 4 supplies the power supply voltage E_x from a power source 43 or supplies the calibration signal to the stimulating means 2 via another amplifier 412b. As a result, an accurate detection signal capable of correcting an error can be obtained.

Fig. 3 illustrates basic structures of semiconductor acceleration sensor of an electrostatic capacity type being manufactured by a silicon micromachining technology.

The acceleration sensor is for obtaining an acceleration by a measurement of an inertia force acting on a predetermined mass in the case where the acceleration exists. The acceleration sensor shown in Fig. 3 is structured such that a load 53 and a cantilever 54 for supporting the load 53 are formed on an intermediate silicon substrate 51 by anisotropic etching. When acceleration α is applied, inertia force ($F_1 = m\alpha$) acts on the load (mass m), causing the load (mass m) to be displaced. On the other hand, the cantilever acts as a spring so that it gives to the load a restoring force expressed by ($F_2 = ax$) (where symbol a denotes a spring constant and x denotes the amount of displacement), the restoring force being given in the direction reverse to the direction of the displacement. As a result, the load is displaced to the position at which the above-described two forces are balanced. From the relationship expressed by ($F_1 = F_2$), the displacement x is given by:

$$x = m\alpha/a \quad (I)$$

Therefore, the acceleration α can be obtained from the displacement x .

The electrostatic capacity type acceleration sensor shown in Fig. 3 includes an upper fixed electrode 55a and a lower fixed electrode 55b formed on the surfaces of the upper substrate 52a and the lower substrate 52b which face the intermediate silicon substrate 51. The fixed electrodes 55a and 55b are electrically connected by conductors 56a and 56b to terminals 57a and 57b, respectively. The electrostatic capacity type acceleration sensor acts to measure the acceleration by obtaining the displacement x of the Equation (I) from the electrostatic capacity between the fixed electrodes and the load (movable electrode).

Thus, an output signal $V(\alpha)$ corresponding to the acceleration can be obtained by the signal processing circuit which processes the electrostatic capacity between the load and the fixed electrode. Since the output and the acceleration α are usually processed so as to keep a linear relationship, the output $V(\alpha)$ is expressed by the following

equation:

$$V(\alpha) = p\alpha + q \quad (II)$$

It is assumed that the acceleration sensor is changed as the time proceeds for some reason. If the change takes place with the linear relationship between the acceleration and the output (substantially) maintained, the output becomes the function of the time. Therefore, the output becomes as follows:

$$V(\alpha, t) = p(t)\alpha + q(t) \quad (III)$$

If the span $p(t)$ and the zero point $q(t)$ of the acceleration-output characteristics (III) have been correctly known, the acceleration α can be accurately obtained by measuring the output $V(\alpha, t)$.

In the case where $p(t)$ and $q(t)$ are unknown in Equation (III), they can be obtained by generating two different accelerations α_1 and α_2 by some method so as to measure the outputs $V(\alpha_1, t)$ and $V(\alpha_2, t)$ which correspond to the two accelerations α_1 and α_2 . Namely, $P(t)$ and $q(t)$ can be obtained from the following simultaneous equation:

$$\left. \begin{aligned} V(\alpha_1, t) &= p(t)\alpha_1 + q(t) \\ V(\alpha_2, t) &= p(t)\alpha_2 + q(t) \end{aligned} \right\} \dots (IV)$$

On the other hand, the acceleration a corresponds to the displacement x of the load in the relationship given by Equation (I). Therefore, determining the acceleration α_1 and α_2 becomes equivalent to determining the displacements x_1 and x_2 which correspond to the accelerations α_1 and α_2 . Thus, the following relationships are obtained from Equations (I) and (IV):

$$\left. \begin{aligned} V(x_1, t) &= p'(t)x_1 + q(t) \\ V(x_2, t) &= p'(t)x_2 + q(t) \end{aligned} \right\} \dots (V)$$

where

$$p'(t) = akp(t)/m \quad (VI)$$

The predetermined displacements x_1 and x_2 shown in Equation (5) can be relatively easily realized. That is, the structure may be such that the load is forcibly displaced by an actuator and the characteristics of the sensor output $V(x, t)$ sharply varies at the predetermined certain displacements x_1 and x_2 . As an alternative to this, the structure may be such that any further displacement is inhibited.

Fig. 4 illustrates an example of the above-described structure, in which stoppers 60a and 60b are provided for the purpose of preventing any displacement which exceeds a predetermined degree even if an acceleration or an external force acts on the load. If the displacements x_1 and x_2 obtained when the loads are brought into contact with the stoppers 60a and 60b are previously known, $p(t)$ and $q(t)$ can be obtained from Equations (V) and (VI) by measuring the outputs $V(x_1, t)$ and $V(x_2, t)$ at this time.

In order to displace the load at a desired time so as to bring it into contact with the stoppers in the case of the electrostatic capacity type sensor, voltage is applied between the load and the upper fixed electrode 55a or the lower fixed electrode 55b, which acts to obtain the electrostatic capacity, so as to apply the electrostatic force between them.

As described above, an advantage can be obtained that the change in the acceleration-output characteristics as

the time proceeds can be corrected by a simple calculation from the output obtained by periodically applying a voltage between the fixed electrodes and the load. Furthermore, the correction can be performed even if the acceleration is being applied to the sensor.

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Claims

1. An electrostatic capacity type acceleration sensor including

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first electrode means (55a, 55b); and
second electrode means (53) disposed in spaced relationship to said first electrode means and supported by flexible spring means (54) for movement toward and away from said first electrode means;

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characterised by further comprising

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means (2, 412b) for applying an exciting voltage across said first and second electrode means so as to displace said second electrode means (53); and
means (4) for measuring the displacement of said second electrode means (53), caused by the application of the exciting voltage, based on a variation in an electrostatic capacity between said first and second electrode means and for comparing the detected displacement with a stored relationship between exciting voltage and displacement of the second electrode means to on-line diagnosing the sensor.

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2. The acceleration sensor of claim 1, wherein said first electrode means comprise a pair of stationary fixed electrodes (55a, 55b) disposed on the opposite sides of said second electrode means (53) and faced toward each other.

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3. A method of on-line diagnosing an electrostatic capacity type acceleration sensor that includes first electrode means (55a, 55b) and second electrode means (53) movable toward and away from said first electrode means, the method comprising the steps of:

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(a) applying an exciting voltage across said first and second electrode means (53, 55a, 55b) so as to displace said second electrode means (53);
(b) detecting the displacement of said second electrode means (53), caused by the application of the exciting voltage, based on a variation in an electrostatic capacity between said first and second electrode means; and
(c) comparing the detected displacement with a stored relationship between exciting voltage and displacement of said second electrode means.

4. The method of claim 3, wherein said exciting voltage is in the form of a pulsated voltage.

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Patentansprüche

1. Beschleunigungssensor, der auf der Grundlage einer elektrostatischen Kapazität arbeitet, mit

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einer ersten Elektrodeneinrichtung (55a, 55b); und
einer von der ersten Elektrodeneinrichtung beabstandeten zweiten Elektrodeneinrichtung (53), die durch eine flexible Federeinrichtung (54) für die Bewegung zu und von der ersten Elektrodeneinrichtung getragen wird;

gekennzeichnet durch

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eine Einrichtung (2, 412b) zum Anlegen einer Anregungsspannung über die ersten und zweiten Elektroden-einrichtungen, so daß die zweite Elektrodeneinrichtung (53) versetzt wird; und
eine Einrichtung (4) zum Messen des durch das Anlegen der Anregungsspannung erzeugten Versatzes der zweiten Elektrodeneinrichtung (53) auf der Grundlage einer Änderung einer elektrostatischen Kapazität zwischen den ersten und zweiten Elektrodeneinrichtungen und zum Vergleichen des aufgenommenen Versatzes mit einer gespeicherten Beziehung zwischen Anregungsspannung und Versatz der zweiten Elektrodeneinrichtung zu einer Online-Diagnose des Sensors.

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2. Beschleunigungssensor gemäß Anspruch 1, wobei die erste Elektrodeneinrichtung ein Paar von fest angeordneten

Elektroden (55a, 55b) aufweist, die an gegenüberliegenden Seiten der zweiten Elektrodeneinrichtung (53) angebracht und aufeinander zu gerichtet sind.

3. Verfahren zur Online-Diagnose eines Beschleunigungssensors, der auf der Grundlage einer elektrostatischen Kapazität arbeitet und eine erste Elektrodeneinrichtung (55a, 55b) und eine zweite Elektrodeneinrichtung (53), die auf die erste Elektrodeneinrichtung zu und von ihr wegbewegt werden kann, aufweist, mit den Verfahrensschritten:

- (a) Anlegen einer Anregungsspannung über die ersten und die zweiten Elektrodeneinrichtungen (53, 55a, 55b), um die zweite Elektrodeneinrichtung (53) zu versetzen;
- (b) Aufnehmen des durch das Anlegen der Anregungsspannung erzeugten Versatzes der zweiten Elektrodeneinrichtung (53) auf der Grundlage einer Änderung in einer elektrostatischen Kapazität zwischen den ersten und den zweiten Elektrodeneinrichtungen; und
- (c) Vergleichen des aufgenommenen Versatzes mit einer gespeicherten Beziehung zwischen Anregungsspannung und Versatz der zweiten Elektrodeneinrichtung.

4. Verfahren gemäß Anspruch 3, wobei die Anregungsspannung eine gepulste Spannung ist.

Revendications

1. Détecteur d'accélération du type à capacité électrostatique comportant

des premiers moyens d'électrode (55a, 55b), et
des seconds moyens d'électrode (53) disposés de manière espacée desdits premiers moyens d'électrode et supportés par des moyens de ressort souple (54) pour se déplacer vers lesdits premiers moyens d'électrode et s'écarter de ceux-ci,

caractérisé en ce qu'il comporte de plus

des moyens (2, 412b) pour appliquer une tension d'excitation à travers lesdits premiers et seconds moyens d'électrode de manière à déplacer lesdits seconds moyens d'électrode (53), et
des moyens (4) pour mesurer un déplacement desdits seconds moyens d'électrode (53), provoqué par l'application de la tension d'excitation, sur la base d'une variation de la capacité électrostatique existant entre lesdits premiers et seconds moyens d'électrode et pour comparer le déplacement détecté à une relation mémorisée existant entre une tension d'excitation et un déplacement des seconds moyens d'électrode pour un diagnostic en ligne du détecteur.

2. Détecteur d'accélération selon la revendication 1, dans lequel lesdits premiers moyens d'électrode comportent deux électrodes fixées de manière stationnaire (55a, 55b) disposées sur les côtés opposés desdits seconds moyens d'électrode (53) et se faisant face l'une l'autre.

3. Procédé de diagnostic en ligne d'un détecteur d'accélération du type à capacité électrostatique qui comporte des premiers moyens d'électrode (55a, 55b) et des seconds moyens d'électrode (53) pouvant se déplacer vers lesdits premiers moyens d'électrode et s'écarter de ceux-ci, le procédé comportant les étapes consistant à :

- (a) appliquer une tension d'excitation à travers lesdits premiers et seconds moyens d'électrode (53, 55a, 55b) de manière à déplacer lesdits seconds moyens d'électrode (53),
- (b) détecter le déplacement desdits seconds moyens d'électrode (53), provoqué par l'application de la tension d'excitation, sur la base d'une variation de la capacité électrostatique existant entre lesdits premiers et seconds moyens d'électrode, et
- (c) comparer le déplacement détecté à une relation mémorisée existant entre une tension d'excitation et un déplacement desdits seconds moyens d'électrode.

4. Procédé selon la revendication 3, dans lequel ladite tension d'excitation est sous la forme d'une tension pulsée.

FIG. 1

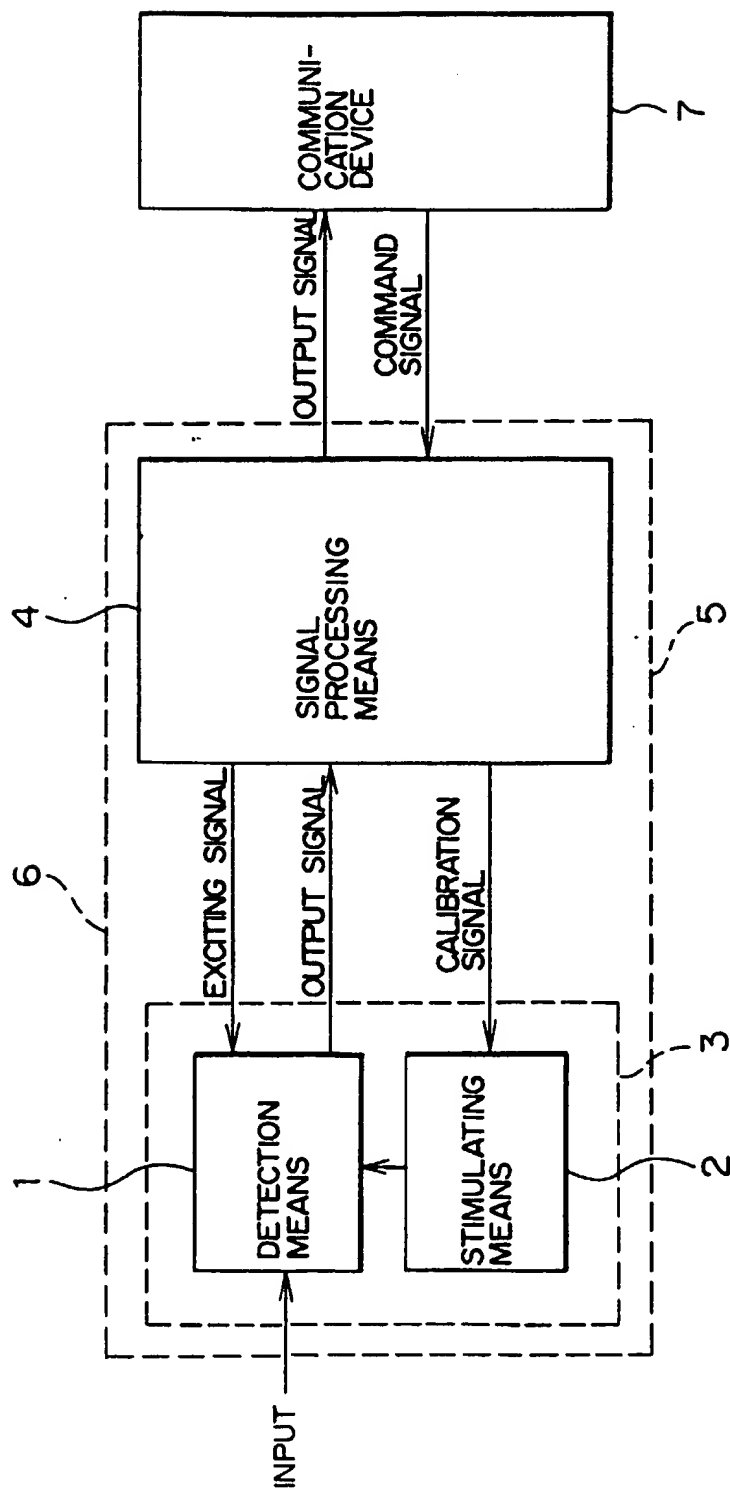


FIG. 2

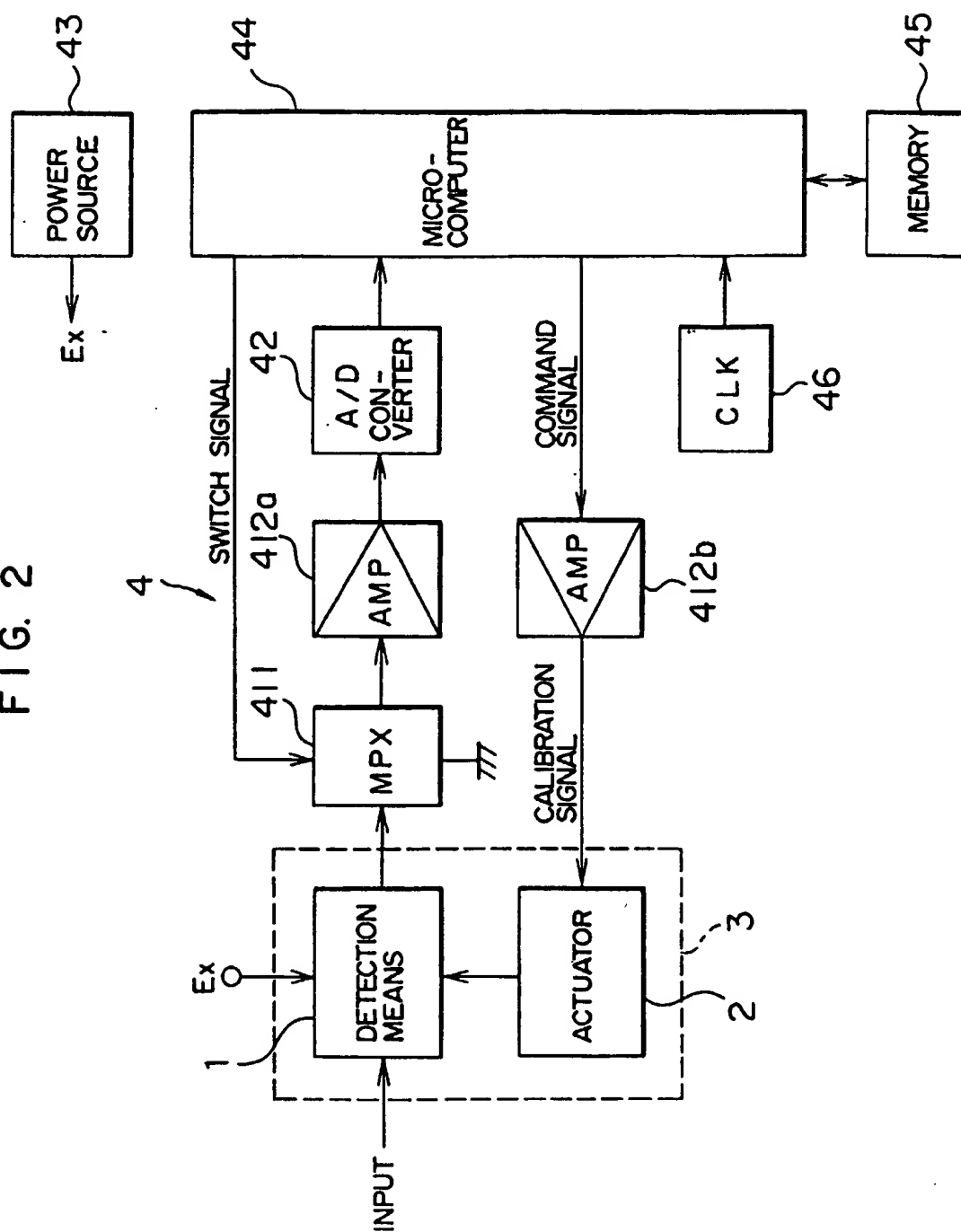


FIG. 3

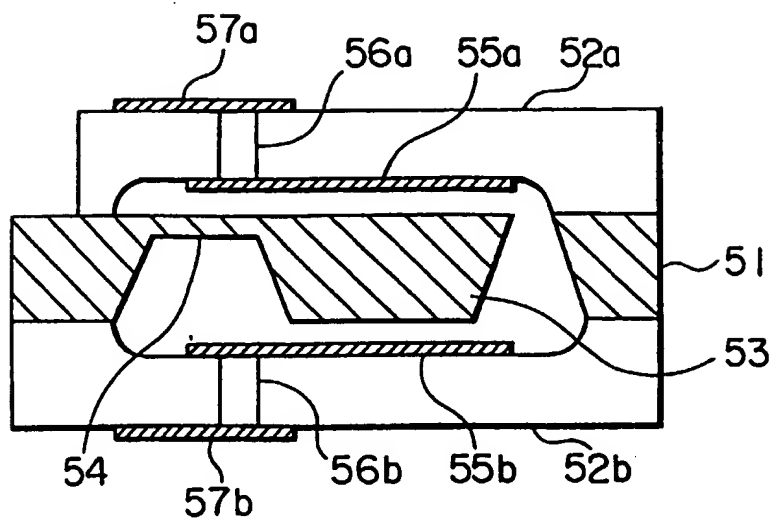


FIG. 4

